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A METHODOLOGY FOR MULTIPLE OBJECTIVE COST/ BENEFIT ANALYSIS OF INTERNAL ACCOUNTING CONTROL SYSTEMS

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Summary:

A systematic, comprehensive methodology for the design and evaluation of internal accounting control systems in an environment of multiple conflicting objectives and complex system interrelationships is presented. The multiple objective decision making (MODM) technique of goal programming is used to model relationships among exposures, causes of exposures and controls. This technique is especially appropriate in decision-making situations in which there exist conflicting objectives concerning costs and effectiveness of alternative internal control configurations. An example system is used to demonstrate the modeling capabilities and interpretation possible with the developed methodology. The role of sensitivity analysis in model implementation is also discussed.

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I. Statement of the Problem

Introduction to Problem Area

In recent years, several developments have led to increased interest by both management and auditors in the design and evaluation of internal accounting control systems. The growing use of computer-based information systems has increased the decision-making burden on both groups. The independent Commission on Auditor's Responsibilities has recommended a management report on the financial statements that presents "management's assessment of the company's accounting system and controls over it."[1]

The SEC has recently issued a proposal that, if adopted, will require outside auditors to review and test clients' internal controls, along with management comment on the adequacy of such controls in annual reports and 10-K forms. Also, ASR no. 242 states that public companies should review their "accounting procedures, systems of internal accounting controls and business practices" in order to take actions necessary to comply with the Foreign Corrupt Practices Act of 1977. The Accounting Standards section of the Act requires public companies to

> ...devise and maintain a system of internal accounting controls sufficient to provide reasonable assurance that -
>
> (i) transactions are executed in accordance with management's general or specific authorization;
>
> (ii) transactions are recorded as necessary (I) to permit preparation of financial statements in conformity with generally accepted accounting principles or any other criteria applicable to such statements, and (II) to maintain accountability for assets;
>
> (iii) access to assets is permitted only in accordance with management's general or specific authorization; and
>
> (iv) the recorded accountability for assets is compared with the existing assets at reasonable intervals and appropriate action is taken with respect to any difference.[2]

The broad objectives of the Accounting Standards section were taken verbatim from the professional auditing literature. These objectives

were originally developed to provide guidance on the independent auditor's study and evaluation of internal control, which serves as a basis for setting the scope of the examination of financial statements. Although auditors test only those controls on which they intend to rely, managements are concerned with the entire system of controls, and need to delineate objectives in more specific terms to guide the selection of controls to be implemented.

The statement that controls should provide "reasonable" assurance that control objectives are met implies that managements are free to take prudent business risks deemed necessary to achieve corporate objectives and that the costs of implemented controls should not exceed the expected benefits.[3] Among the costs considered in the literature are out-of-pocket costs of installing control features, performing control procedures, searching for errors when their existence has been signaled and making necessary corrections.

The primary benefit of an individual control or group of controls is the reduction of one or more exposures (expected dollar losses due to errors or irregularities which cause them). Types of exposures include unintentional loss of physical assets, money, claims to money and other assets; business expenses which could be readily avoided and loss of revenues to which the organization is entitled; penalties which must be paid as a result of judicial or regulatory proceedings; and intentional misappropriation of funds. The purpose of controls is to reduce exposures by preventing or detecting and correcting the errors or irregularities which cause them.[4]

Complicating Factors

The process of selecting which controls to implement is complicated by two factors. The first is that each control has at least two important, incommensurable attributes: (1) costs, out-of-pocket installation and operating and (2) effectiveness (defined as the probability that the target cause of exposure will not occur or will be detected and corrected, depending on the control during a specified period of time). Managerial objectives with respect to these attributes inherently conflict. Management presumably wishes to minimize the total out-of-pocket costs of the control system or a particular subsystem while maximizing its effectiveness, subject to constraints dictated by environment or resources. However, the least expensive controls or control combinations may also be the least effective.

The second complicating factor is that system interrelationships may be extremely complex. Three situations can exist: (1) alternative controls or groups of controls may affect (prevent or detect and correct) a particular cause of exposure, (2) individual controls may affect more than one cause[5] and (3) individual causes may generate more than one exposure.[6] (See Table 1). The complexity resulting from these two factors necessitates a systematic, approach to internal accounting control system design and evaluation.

Previous Research Efforts

A search of the professional and academic accounting literature reveals that a satisfactory approach has not been developed at this time. A recent publication by the Institute of Internal Auditors recommends that the decision-maker "analyze" the various controls that would affect causes of a particular exposure and then implement "only those which are

sufficient to effectively limit the exposure."[7] Arthur Andersen & Co. recommends that "judgment" be used to select controls which will prevent causes of exposures if those exposures are judged to be material.[8] In 1974, Cushing stated that the closest approach to an analytical technique in actual design and evaluation of internal control systems may be the auditor's widely used internal control questionnaire.[9] This belief is reinforced by the AICPA Special Advisory Committee on Internal Accounting Control, which recently concluded that control procedures and techniques have evolved over the years based on the judgments of individual managements of their necessity or usefulness in specific situations.[10]

Only recently have accounting researchers begun to apply mathematical modeling techniques to the problem of internal control system design and evaluation. Cushing applied reliability theory to the design problem;[11] Yu and Neter used Markov theory to assess the reliability of a system of controls;[12] and Burns and Loebbecke demonstrated the use of simulation in internal control evaluation by external auditors.[13] These research efforts demonstrate the usefulness of different mathematical modeling techniques in attacking various aspects of the problem. However, because of their particular purposes, the resulting models do not incorporate the conflicting and incommensurable managerial objectives of minimizing out-of-pocket costs and maximizing effectiveness. Furthermore, they are not designed to reflect the complex interrelationships among exposures, causes and controls that characterize real-world situations. Not surprisingly, the Special Advisory Committee on Internal Accounting Control recently stated that "companies do not have a comprehensive theoretical model to use in making informed, supportable judgments on the cost-benefit decisions implicit in developing their accounting control procedures and techniques."[14]

Statement of Purpose

The purpose of the present paper is to demonstrate the use of a systematic, comprehensive methodology in the design and evaluation of internal accounting control systems in an environment of multiple conflicting objectives and complex system interrelationships. For reasons forthcoming, the multiple objective decision making (MODM) technique of goal programming will be used to model relationships among exposures, causes of exposures and controls. This technique is especially appropriate in decision-making situations in which there exist conflicting objectives concerning costs and effectiveness of alternative internal control configurations. The role of sensitivity analysis in model implementation will also be discussed.

It is anticipated that the methodology will provide management with not only the analytical benefits of a systematic approach to internal control system design and evaluation, but also increasingly important documentation that such an analysis has been made. Also, the methodology can provide independent auditors with an opportunity to improve their assessment of an internal control system for use in (a) setting the scope of the examination of financial statements and (b) reviewing management comment on the adequacy of the control system.

II. Methodological Approaches to Multiple Objective Problems

Taxonomy of Methods

The purpose of MODM methods is to consider the various interactions within the design constraints and select the best alternative configuration of decision variables which satisfies the decision-maker (DM) by attaining acceptable levels of a set of quantifiable objectives.[15]

Hwang and Masud classify MODM methods which require DM preference information as a priori, interactive or a posteriori, depending on the stage of the solution procedure at which such information is required.[16] (See Figure 1.)

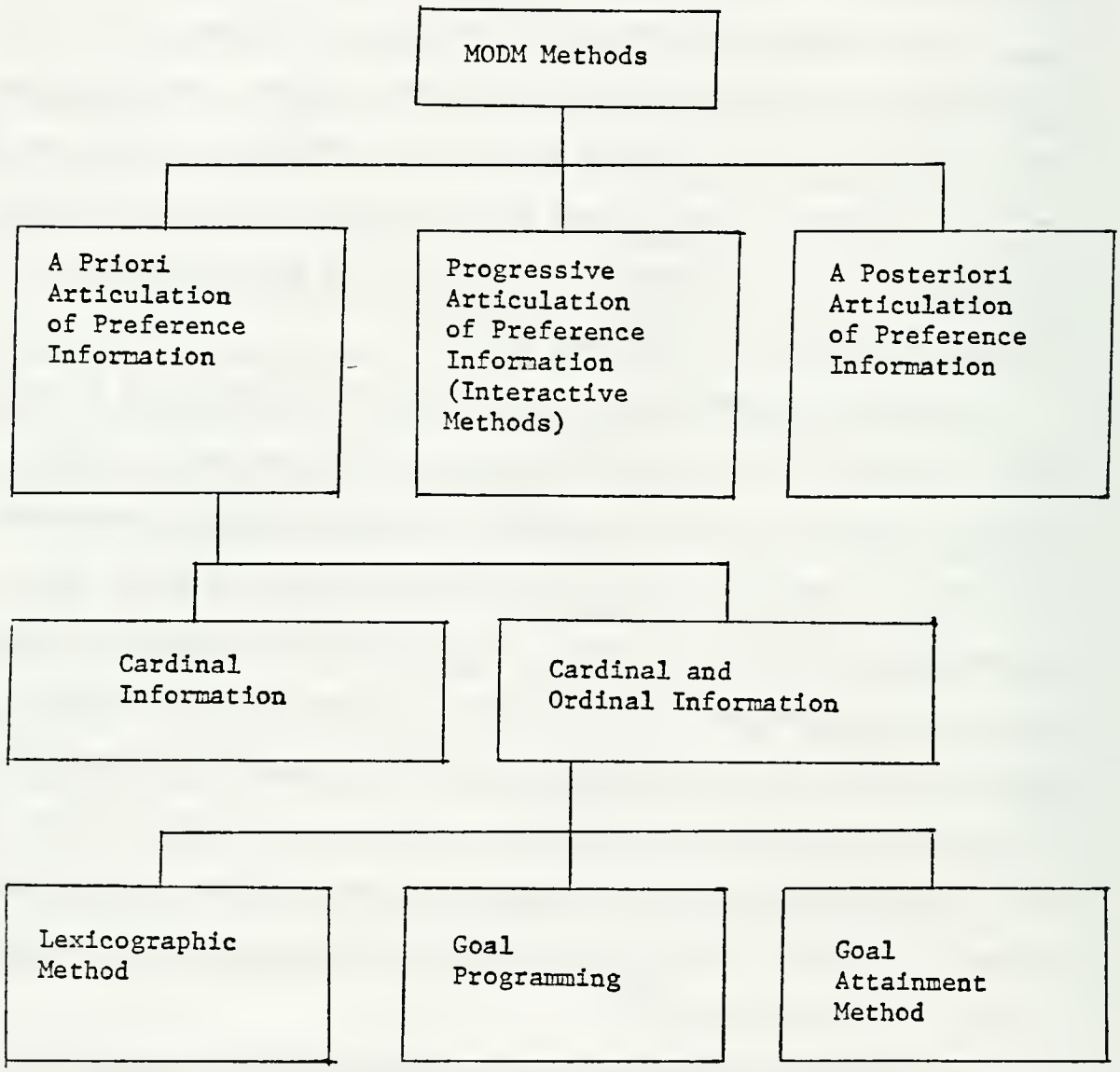
A priori methods require the DM to provide preference information to the analyst before he actually solves the problem. The information may be either cardinal or mixed (cardinal and ordinal). In the case of cardinal information, the DM must state specific preference levels or trade-offs. If the information is mixed, the DM must also rank the objectives in order of their importance.[17]

Interactive methods rely on the progressive articulation of the DM's preferences during exploration of the criterion space. These methods assume that the DM is unable to indicate a priori preferences but that he is able to give preference information at a local level concerning a particular solution. The progressive articulation takes place through a DM analyst or DM machine dialogue at each iteration. The DM is asked to give preference information regarding trade-offs between attainment levels of objectives based on the current solution, or set of solutions, in order to advance to a new solution. As the solution process progreses, the DM not only indicates his preferences, but also learns about the problem.[18]

Methods for a posteriori articulation of preference information determine a subset of the problem's nondominated solutions (those in which no objective can be improved without a simultaneous detriment to at least one other objective). From this subset the DM chooses the most satisfactory solution, making implicit trade-offs among objectives based

Figure 1

Taxonomy of MODM Methods Requiring
DM Preference Information



on some previously unindicated or nonquantifiable criterion or criteria. The trade-off information, which remains implicit, is received from the DM after the method has terminated and the subset of nondominated solutions has been generated.[19]

For internal control system design and evaluation, methods classified as either interactive or a posteriori were rejected. For many interactive methods there is no guarantee that the preferred solution can be obtained within a finite number of interactive cycles, and much more time and effort is required of the DM than is required with a priori methods.[20] A posteriori methods are severely limited in practical applicability because they usually generate a large number of nondominated solutions, making it very difficult for the DM to choose the one which is most satisfactory.[21] For these reasons, and because it is reasonable to believe that management can state a priori preferences concerning their internal control objectives, an a priori method was chosen.

The method, goal programming, requires the DM to give the analyst ordinal as well as cardinal preference information. The appropriateness of ordinal preferences in MODM problems is well established. Easton states that virtually every multiple objective decision problem involves criteria of differing importance to the DM, and that "some objectives must be given priority over others."[22] Keeney and Raiffa found that "almost everyone who has seriously thought about the objectives in a complex problem [one involving multiple attributes and conflicts among objectives] has come up with some sort of hierarchy of objectives."[23] In the area of interest, Fisher believes that "a firm must rank its control priorities in some systematic fashion as a preliminary step to any

detailed analysis of control," and that this ranking should be used as a basis for cost/benefit analysis and selection of controls to be implemented.[24]

Goal programming was chosen over the lexicographic and goal attainment methods, the other a priori MODM methods which require both cardinal and ordinal preference information. The lexicographic method is similar to goal programming but is less flexible in that it does not allow the DM to specify goals.[25] (Goals are specific levels of achievement toward which to strive, whereas objectives are general "directions" toward which to strive.) The goal attainment method is a variation of goal programming which requires the DM to specify not only the desired goals but also a vector of numerical weights relating the relative under- or overattainment of the goals. When some goals are under- and some overattained, deriving the vector of weights is very difficult.[26] Since both under- and overattainment of internal control goals is likely, this method was also considered less appropriate than goal programming for the research problem.

Goal Programming

The number of accounting and other applications of goal programming is continually increasing. Charnes, Cooper and Ijiri applied the method to breakeven budgeting.[27] Killough and Souders modeled the manpower resource allocation problem of CPA firms.[28] Charnes, Colantoni, Cooper and Kortanek discussed the application of goal programming to social planning.[29] Other applications include advertising media planning,[30] production planning,[31] academic planning,[32] medical care planning,[33] multiple criteria evaluation of information systems[34] and multiple objective

capital budgeting.[35] The use of the method in internal control system design and evaluation represents a new application.

An analysis of the features of the goal programming methodology both reveals its appropriateness for the present problem and provides support for the contention that it is an appropriate and flexible method for solving complex decision problems involving multiple conflicting objectives.[36] Goal programming was introduced by Charnes and Cooper as a tool to resolve infeasible linear programming (LP) problems. LP may be used to solve multiple objective problems by introducing objectives other than the objective function as model constraints. However, the optimal solution of an LP problem must satisfy all constraints. Because goals set by management are often achievable only at the expense of other goals, it is quite possible that all constraints cannot be satisfied. If not, the LP problem is called "infeasible."

In goal programming, the objective is not to maximize or minimize a single objective criterion directly but to minimize the positive and negative deviations from goals based on the priority and/or relative importance assigned to them. The DM must therefore establish a hierarchy of importance among his conflicting goals so that lower-priority goals are considered only after higher-priority goals are satisfied to the extent possible or desirable. The model does not produce an optimal solution (one which optimizes each objective simultaneously)[37] but produces the "best" or "preferred" solution (the one which minimizes deviations from the goals, given the DM's stated preferences).[38] Both an overall figure of merit and deviation values for each goal are produced.

One additional comparison between goal programming and LP highlights the appropriateness of the former for internal control system design and evaluation. To properly use LP, the DM must be able to quantify relationships among variables in terms of cardinal numbers. Unfortunately, the DM may be unable to express an objective such as "minimize the loss of goodwill due to the undetected occurrence of cause x" in terms of dollars without a considerable degree of fabrication or distortion of information. However, he will often be able to state upper or lower limits (i.e., goals) for such objectives in terms of some other, more appropriate unit of measure (e.g., probability).[39] An example goal is "minimize the loss of goodwill due to the undetected occurrence of cause x by installing controls with a combined effectiveness in controlling cause x of at least .99." Goal programming allows the DM to formulate such goals and then assign a priority to the attainment of each of them. This ordinal solution feature is especially significant in light of the incommensurable nature of internal control objectives.

General Goal Programming Model

The goal programming formulation employed in the present paper is based on the approach taken by Charnes and Cooper[40] and Lee.[41] The general formulation is:

$$\text{Minimize } Z = (P^{+} \cdot W^{+} \cdot D^{+}) + (P^{-} \cdot W^{-} \cdot D^{-})$$

Subject to

$$A \cdot \beta + ID^{-} - ID^{+} = G$$

$$\beta \geq 0$$

where

β is an (Mx1) vector of decision variables

A is an (NxM) matrix of technological coefficients

G is an (Nx1) vector of goals

$D^+(D^-)$ is an (Nx1) vector of positive (negative) deviations from goal vector G

$P^+(P^-)$ is a (1xN) vector of preemptive priority factors assigned to positive (negative) deviations

$W^+(W^-)$ is an (NxN) diagonal matrix of weights reflecting the relative importance of positive (negative) deviations within priority levels

M is the number of decision variables

N is the number of goals

I is the appropriate identity matrix

The goal programming solution procedure minimizes the objective function by driving the values of the ranked and weighted deviations as close to zero as possible through manipulation of the values of the decision variables. The objective function is constructed in the following manner.

First, each goal is analyzed to determine whether its over- or under-attainment is acceptable. If over- (under-) attainment is acceptable, the positive (negative) deviational variable can be omitted from the objective function. For example, if the goal is to achieve a contribution to fixed costs and profit of $10,000, a positive deviation is acceptable and the positive deviational variable can be omitted.

Next, the positive and negative deviational variables to be included in the objective function are grouped in ordered sets according to importance. Each variable in the j^{th} set is assigned a "preemptive priority factor" P_j, which is interpreted via the relationship $P_j >>> P_{j+1}$ to mean

that no number n, however large, can make nP_{j+1} greater than or equal to P_j.

Finally, weights may be assigned to deviational variables having the same preemptive priority factor. The criterion to be used is the minimization of unsatisfactory achievement reflected in positive values of deviational variables at each priority level. Because weighting factors represent relative amounts of unsatisfactory achievement, deviations from goals within a priority level must be commensurable.[42]

III. Internal Accounting Control Model

Purpose and Components

The purpose of the internal accounting control model is (1) to demonstrate the applicability of the general goal programming methodology to the problem area and (2) to provide a base for exploring the potential of the methodology for providing decision-making insights. The basic components of the model are exposures, causes of exposures, controls and processes, which are defined below.

An exposure is an adverse effect of some error or irregularity (cause), stated in dollars. A control is a procedure or mechanism designed to prevent or detect a cause. An exposure must be caused; it does not arise simply due to lack of controls. The purpose of controls is to reduce exposures by directly impacting their causes.[43]

Consider the computation of an employee's gross pay by multiplying hours worked by hourly wage. If the computation is made incorrectly and this error (cause) is not detected, a loss of cash (exposure) equal to the (assumed positive) difference between the computational result and correct gross pay could result. To detect such an error, a redundant

processing control could be employed: two payroll clerks could make each gross pay calculation and compare their results for equality. Although this control is not foolproof, it would function properly a high percentage of the time, and detected errors could be corrected before they caused exposures.

In the goal programming model, controls are evaluated in groups of one or more called processes. Most real-world internal control situations are characterized by multiple controls for each cause of exposure.[44] The combined effectiveness of these controls--the probability that the target cause will not occur or will be detected and corrected, given the implementation of the entire group of controls--is the relevant measure for system analysis. The use of processes enables the DM to reflect the fact that the effectiveness of a group of controls is not always a straightforward extension of the effectiveness of each individual control.

An important feature of this model is its ability to handle the complex interrelationships between causes, exposures, processes and controls. Table 1 characterizes a simple, but typical situation where many types of these interrelationships exist. Exposure 1 may be caused by cause 1 or cause 2; exposure 2 may be caused only be cause 1. To prevent or detect cause 1, for example, process 1 (controls 1, 2, and 3) or process 2 (controls 1, 2 and 4) may be implemented. (Alternative processes to be considered are specified by the DM.) Also, each of controls 1, 2, 3 and 4 is a component of two or more different processes. In this example, then, the following types of interrelationships are found: (1) one cause of more than one exposure, (2) alternative processes for one cause, and (3) one control to prevent or detect more than one cause.

Table 1

Interrelationships Among Model Components

Cause	Exposure	Process	Control				
			1	2	3	4	5
1	1,2	1	✓	✓	✓		
		2	✓	✓		✓	
2	1	3	✓		✓	✓	
		4	✓		✓		✓

Model Construction: Background

An internal control system modeled by the developed methodology could reflect all three of these interrelationships. However, the model presented in the present paper to illustrate the goal programming methodology will be based in the situation in Table 1 but will ignore exposure 2, and, therefore, will not illustrate type (1) above.

The constraints and goals to follow are applicable to both preventive and detective controls. Preventive controls, such as the prenumbering of checks and other forms, are designed to prevent causes of exposure from occurring. These controls may involve one-time installation costs and/or operating costs each time they are employed. Detective controls, such as the redundant processing previously mentioned, are designed to signal a cause of exposure after it has occurred. When one of these controls signals the existence of a cause, that cause should be investigated to determine what corrective action is necessary. Costs of detective controls include one-time installation costs and costs of searching for errors and making whatever corrections are necessary when errors are signaled.

The abstract situation to be modeled is as follows (see Table 2 for cost and effectiveness information). If no controls were implemented for cause 1, the probability would be .30 that an expected exposure of $300,000 would result during a specified period of time. The expected exposure, therefore, would be $90,000. If process 1 were implemented, the expected exposure would be $1,200 ($300,000 x .004). If process 2 were implemented, the expected exposure would be $3,000 ($3000,000 x .010). If no controls were implemented for cause 2, the probability

Table 2

Cost and Effectiveness Information

	Costs	1 - Effectiveness
Control 1	$ 5,000	-
Control 2	$20,000	-
Control 3	$35,000	-
Control 4	$25,000	-
Control 5	$ 5,000	-
Process 1	-	.004
Process 2	-	.010
Process 3	-	.008
Process 4	-	.015

would be .40 that an expected exposure of $1,000,000 would result during the period, giving an expected exposure of $400,000. If process 3 were implemented, the expected exposure would be $8,000 ($1,000,000 x .008). Implementation of process 4 would yield an expected exposure of $15,000 ($1,000,000 x .015).

Model Construction: Constraints and Objective Function

For the current model, the task of the goal programming procedure is to determine which processes to implement, if any, given the following assumed management objectives: (1) minimize the total of (a) out-of-pocket costs of controls and (b) expected exposures during the period; (2) implement at least one process for each cause; and (3) minimize the probability of exposure from each cause. Zero-one decision variables are used to indicate which processes and component controls should be implemented. The model consists of several groups of constraints and goals.

The first group of constraints consists of one for each control. These constraints insure that if any process x_j containing control c_i is chosen for implementation (assigned a value of 1), the control will also be chosen. The general form is:

$$(1) \qquad r_i c_i - \sum_{j}^{T} x_{ij} \geq 0 \qquad \forall i$$

where T = number of processes in model

r_i = number of processes containing control i

$$x_{ij} = \begin{cases} x_j \text{ if process j contain control i} \\ 0 \text{ otherwise} \end{cases}$$

$$c_i = \begin{cases} 1 \text{ if control } i \text{ is chosen} \\ 0 \text{ otherwise} \end{cases}$$

$$x_j = \begin{cases} 1 \text{ if process } j \text{ is chosen} \\ 0 \text{ otherwise} \end{cases}$$

The specific constraints for the example system are:

$$4c_1 - x_1 - x_2 - x_3 - x_4 \geq 0$$

$$2c_2 - x_1 - x_2 \geq 0$$

$$2c_3 - x_1 - x_3 - x_4 \geq 0$$

$$2c_4 - x_2 - x_3 \geq 0$$

$$c_5 - x_4 \geq 0$$

The second group of constraints consists of one for each process. These constraints insure that if all controls in process x_j are chosen for implementation, that process is chosen (i.e., the system is "given credit for" the process). The general form is:

$$(2) \qquad \sum_{i}^{S} c_{ij} - s_j \leq s_j - 1 \qquad \forall j$$

where S = number of controls in the model

s_j = number of controls in process j

$$c_{ij} = \begin{cases} c_i \text{ if control is is a component of process } j \\ 0 \text{ otherwise} \end{cases}$$

The specific constraints for the example system are:

$$c_1 + c_2 + c_3 - x_1 \leq 2$$

$$c_1 + c_2 + c_4 - x_2 \leq 2$$

$$c_1 \quad + c_3 + c_4 \quad - x_3 \leq 2$$

$$c_1 \quad + c_3 \quad + c_5 - x_4 \leq 2$$

The first managerial objective for the current example, minimization of the sum of control costs and expected exposures, is reflected in a single goal. The goal contains non-decision variables V_k and Y_{jk} which are associated with expected exposures under different process implementation assumptions. The general form is:

$$(3) \qquad \sum_{i}^{S} g_i c_i + \sum_{kl}^{KE} d_{kl} b_k V_k + \sum_{jkl}^{TKE} d_{kl} e_{jk} Y_{jk} - d^+ = 0$$

where K = number of causes in the model

E = number of exposures in the model

g_i = cost of control i during the decision period

d_{kl} = expected exposure l given cause k

b_k = probability of cause k if no process is implemented to control cause k

e_{jk} = (1 - effectiveness) of process j in controlling cause k

$$V_k = \begin{cases} 1 & \text{if no control process is implemented to control cause k} \\ 0 & \text{otherwise} \end{cases}$$

$$Y_{jk} = \begin{cases} 1 & \text{if process j controls cause k and the probability of of cause k occurring and not being detected and corrected, given the model soluiton, is } e_{jk} \\ 0 & \text{otherwise} \end{cases}$$

The specific goal for the example system is:

$$5{,}000c_1 + 20{,}000c_2 + 35{,}000c_3 + 25{,}000c_4 + 5{,}000c_5 + 300{,}000(.30)V_1$$

$$+ 1{,}000{,}000(.40)V_2 + 300{,}000(.004)Y_{11} + 300{,}000(.010)Y_{21} +$$

$$+ 1{,}000{,}000(.008)Y_{32} + 1{,}000{,}000(.015)Y_{42} - d_1^+ = 0$$

The next group of constraints insure that, for each cause, (1) if more than one process is implemented to control the cause, the total of expected exposures due to the cause is the lowest total associated with the implemented processes and (2) if no process is implemented to control the cause, the total of uncontrolled expected exposures due to the cause results. The general forms are:

$$(4) \qquad \sum_{j}^{T} Y_{jk} + V_k = 1 \qquad \forall k$$

$$(5) \qquad Y_{jk} - X_j \leq 0 \qquad \forall j,k$$

The specific constraints for the example system are:

$$Y_{11} + Y_{21} + V_1 = 1$$

$$Y_{11} - X_1 \leq 0$$

$$Y_{21} - X_2 \leq 0$$

$$Y_{32} + Y_{42} + V_2 = 1$$

$$Y_{32} - X_3 \leq 0$$

$$Y_{42} - X_4 \leq 0$$

The second managerial objective, implementation of at least one process for each cause, is reflected in one goal for each cause. The general form is:

$$(6) \qquad \sum_{j}^{T} X_{jk} + d^- - d^+ = 1 \qquad \forall k$$

where $X_{jk} = \begin{cases} X_j \text{ if process } j \text{ controls cause } k \\ 0 \text{ otherwise} \end{cases}$

The specific system goals are:

$$x_1 + x_2 + d_2^- - d_2^+ = 1$$

$$x_3 + x_4 + d_3^- - d_3^+ = 1$$

The third managerial objective, minimization of the probability of exposure from each cause, is also reflected in one goal for each cause. The general form is:

$$(7) \qquad \sum_j^T e_{jk}Y_{jk} + b_kV_k - d^+ = 0 \qquad \forall k$$

The specific goals for the example system (after multiplying the probabilities by 1,000 to convert them to integers) are:

$$4Y_{11} + 10Y_{21} + 300V_1 - d_4^+ = 0$$

$$8Y_{32} + 15Y_{42} + 400V_2 - d_5^+ = 0$$

(Note: Goals for both objective one and objective three require constraints (4) and (5).)

The final group of constraints restrict the values of zero-one variables. The constraints are:

$$(8) \qquad c_i, x_j, V_k, Y_{jk} = 0,1 \qquad \forall i,j,k,l$$

The general form of the internal control model objective function is:

$$\text{Min } Z = (P^+ \cdot W^+ \cdot D^+) + (P^- \cdot W^- \cdot D^-)$$

If the preceding order of objectives is assumed to be management's hierarchy, the objective function of the example system is the minimization

of the sum of five ranked and weighted deviational variables: d_1^+, the positive deviation from the first objective goal; d_2^- and d_3^-, negative deviations from the second objective goals; and d_4^+ and d_5^+, positive deviations from the third objective goals. Positive deviations from the second objective goals are acceptable, therefore d_2^+ and d_3^+ are omitted. d_3^- is assigned a weight of 4 at priority level 2 because the expected exposure from cause 2 ($400,000) is approximately 4 times that from cause 1 ($90,000) if no processes are chosen. d_4^+ and d_5^+ are assigned weights of 1 at priority level 3 because the probability of exposure from cause 1 (.30) is approximately equal to that from cause 2 (.40) if no processes are chosen.

The objective function of the example system is therefore:

$$\text{Min } Z = P_1 d_1^+ + P_2 d_2^- + P_2 4 d_3^- + P_3 d_4^+ + P_3 d_5^+$$

Model Construction: Final Formulation

Grouping the objective function, goals and constraints of the preceding section results in the following general internal accounting model:

$$\text{Min } Z = (P^+ \cdot W^+ \cdot D^+) + (P^- \cdot W^- \cdot D^-)$$

S.T.

(1) $$r_i c_i - \sum_j^T x_{ij} \leq 0 \qquad \forall i$$

(2) $$\sum_i^S c_{ij} - x_j \leq s_j - 1 \qquad \forall j$$

$$(3) \qquad \sum_{i}^{S} g_i c_i + \sum_{kl}^{KE} d_{kl} b_k V_k + \sum_{jkl}^{TKE} d_{kl} e_{jk} Y_{jk} - d^+ = 0$$

$$(4) \qquad \sum_{j}^{T} Y_{jk} + V_k = 1 \qquad \forall k$$

$$(5) \qquad Y_{jk} - x_j \leq 0 \qquad \forall j,k$$

$$(6) \qquad \sum_{j}^{T} x_{jk} + d^- - d^+ = 1 \qquad \forall k$$

$$(7) \qquad \sum_{j}^{T} e_{jk} Y_{jk} + b_k V_k - d^+ = 0 \qquad \forall k$$

$$(8) \qquad c_i, x_j, V_k, Y_{jk} = 0,1 \qquad \forall i,j,k,l$$

Similarly, the specific example model is:

$$\text{Min } Z = P_1 d_1^+ + P_2 d_2^- + P_2 4 d_3^- + P_3 d_4^+ + P_3 d_5^+$$

S.T.

$$4c_1 - x_1 - x_2 - x_3 - x_4 \geq 0$$

$$2c_2 - x_1 - x_2 \geq 0$$

$$3c_3 - x_1 - x_3 - x_4 \geq 0$$

$$2c_4 - x_2 - x_3 \geq 0$$

$$c_5 - x_4 \geq 0$$

$$c_1 + c_2 + c_3 \qquad - x_1 \leq 2$$

$$c_1 + c_2 \qquad + c_4 \qquad - x_2 \leq 2$$

$$c_1 \qquad + c_3 + c_4 \qquad - x_3 \leq 2$$

$$c_1 \qquad + c_3 \qquad + c_5 - x_4 \leq 2$$

$$5{,}000c_1 + 20{,}000c_2 + 35{,}000c_3 + 25{,}000c_4 + 5{,}000c_5 + 300{,}000(.30)V_1$$

$$+ 1{,}000{,}000(.40)V_2 + 300{,}000(.004)Y_{11} + 300{,}000(.010)Y_{21}$$

$$+ 1{,}000{,}000(.008)Y_{32} + 1{,}000{,}000(.015)Y_{42} - d_1^+ = 0$$

$$Y_{11} + Y_{21} + V_1 = 1$$

$$Y_{11} - x_1 \leq 0$$

$$Y_{21} - x_2 \leq 0$$

$$Y_{32} + Y_{42} + V_2 = 1$$

$$Y_{32} - x_3 \leq 0$$

$$Y_{42} - x_4 \leq 0$$

$$x_1 + x_2 + d_2^- - d_2^+ = 1$$

$$x_3 + x_4 + d_3^- - d_3^+ = 1$$

$$4Y_{11} + 10Y_{21} + 300V_1 - d_4^+ = 0$$

$$8Y_{32} + 15Y_{42} + 400V_2 - d_5^+ = 0$$

$$c_i, x_j, V_k, Y_{jk} = 0, 1$$

Example Model Solution and Interpretation

For this model, the solution procedures produces the following objective function deviational variable values and non-zero zero-one variable values:

$$c_1 = c_2 = c_3 = c_5 = 1$$

$$x_1 = x_4 = 1$$

$$Y_{11} = Y_{42} = 1$$

$$d_1^+ = 81,200$$

$$d_2^- = d_3^- = 0$$

$$d_4^+ = 4$$

$$d_5^+ = 15$$

The model solution specifies implementation of processes 1 and 4 at a total control cost plus expected exposure of $81,200. This amount may be verified by adding the costs of chosen controls 1, 2, 3 and 5 and the expected exposures associated with Y_{11} and Y_{42} in the first goal.

The solution demonstrates that analysis of one cause at a time can result in a less satisfactory control selection by the DM than does a single analysis of interrelated causes (except in the special case in which both analyses produce the same results). Focusing on cause 1, the total of costs and expected exposure from implementation of process 1 alone is $61,200 ($5,000(c_1) + $20,000($c_2$) + $35,000($c_3$) + $1,200(exposure)). The total for process 2 alone is $53,000($5,000(c_1) +

$\$20,000(c_2) + \$25,000(c_4) + \$3,000(\text{exposure})$). However, choice of process 1 results in a lower overall total because component control 3 is also a component of process 4, which is chosen. For similar reasons, interrelated exposures should be analyzed together.

Sensitivity Analysis

An analysis of the effects of parameter changes after determining the optimal (or, in the case of goal programming, the preferred) solution is an important part of any mathematical modeling solution process. This postoptimality study is known as sensitivity analysis. Because there will usually exist some degree of uncertainty concerning real-world internal accounting control model parameters--e.g., priority factors goals and technological coefficients--sensitivity analysis is a vital part of the goal programming methodology being developed. If, during the analysis, the best solution to a particular model is found to be relatively sensitive to changes in the values of certain parameters, management should consider allocating additional organizational resources to the collection and refinement of data pertaining to those parameters. If the best solution is relatively insensitive to such changes, management may wish to use those resources in some more promising endeavor.

Although sensitivity analysis is an important follow-up to the initial solution of the model, there are no established procedures to follow in conducting such an analysis on an integer goal programming model. Even without the added complexity of a multidimensional objective function, sensitivity analysis in integer linear programming models is far more complex than its counterpart in continuous models.[45] The dual solution does not have an equivalent meaning to the dual solution

in the continuous model, and the dual of the integer goal program has yet to be developed. Due to the lack of systematic procedures, Jensen recommends that the analyst rely on intuition and ingenuity in performing sensitivity analysis on an integer programming model.[46]

Current research is being conducted on the sensitivity analysis of the developed internal accounting control model. It includes analysis of the effects of changes in preemptive priority factors, goals and technological coefficients (control costs, process effectiveness and dollar values of exposures). A further possibility is to add a budgetary goal to the current set of management goals. The anticipated effects of making such modifications are changes in (1) individual controls and processes suggested for implementation, (2) total control costs and expected exposures and (3) the probabilities of individual causes.

IV. Conclusion

To summarize, the purpose of the present paper is to demonstrate the use of a systematic, comprehensive methodology in the design and evaluation of internal accounting control systems in an environment of multiple conflicting objectives and complex interrelationships among exposures, causes of exposures and controls. It is anticipated that use of the methodology would provide management with decision-making insights that would be unavailable if control system components were evaluated in a manner which ignored these interrelationships. Also, system models would provide important documentation that a thorough analysis of costs and benefits preceded the implementation of controls.

Footnotes

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[6]Marguerite Fisher, "Internal Controls: Guidelines for Management Action," Journal of Accounting, Auditing and Finance 1 (Summer 1978), p. 354.

[7]Mair, Wood and Davis, Computer Control and Audit, p. 14.

[8]Arthur Andersen & Co., A Guide for Studying and Evaluating Internal Accounting Controls (New York: Arthur Andersen & Co., 1978), p. 196.

[9]Cushing, "A Mathematical Approach to the Analysis and Design of Internal Control Systems," p. 24.

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[15]Ching-Lai Hwang and Abu Syed Md. Masud, Multiple Objective Decision Making—Methods and Applications (New York: Springer-Verlag, 1979), pp. 6-7.

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[17]Ibid., p. 30.

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[20]Ibid., p. 103.

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[26]Ibid., p. 97.

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[32]Ibid.

[33]Ibid.

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[36]Sang M. Lee, Linear Optimization for Management (New York: Petrocelli/Charter, 1976), p. 177.

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[38]Ibid., pp. 20, 56. Also see Herbert A. Simon, "Rational Decision Making in Business Organizations," The American Economic Review 69 (September 1979), p. 502-503.

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